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COTTON DISEASES

and their CONTROL

Disease.	Control measures.
Wilt	Use wilt-resistant varieties. Rotate to reduce root-knot.
Root-knot	Rotate with immune crops.
Anthracnose	Select disease-free seed of resistant varieties. Rotate crops.
Bacterial blight	Select disease-free seed. Rotate crops.
Shedding of bolls	Conserve soil moisture— by increasing the humus supply. by late shallow cultivation.
Rust	Add humus to the soil. Use potash fertilizers. Drain wet land.
Texas root-rot	Plow deeply in the fall. Rotate crops.

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief
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COTTON DISEASES AND THEIR CONTROL.

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IMPORTANCE OF COTTON DISEASES.

Cotton is the most important crop in the Southern States and is second only to corn in farm value for the entire country. Several important diseases attack the crop and reduce the yield materially. In some sections certain diseases are so prevalent and severe that profitable cotton crops can not be grown on infested fields by the methods usually employed, but by the adoption of the control measures described in this bulletin good crops can be produced.

The principal cotton diseases which cause damage in the Southern States are described and illustrated in the following pages and the best-known methods of controlling them are described.

WILT.

The disease which causes the largest losses to the cotton crop in the United States is commonly known as wilt, or black-root. The most noticeable symptom is the wilting and death of affected plants. The dead roots of diseased plants turn black, and from this fact comes the common name "black-root."

This disease is widely distributed throughout the sandy soils of the cotton belt from Virginia to Texas, and is spreading year by year to new localities. It is present every year, though in some seasons the losses are heavier than in others. In severe cases the yield is reduced as much as 75 to 90 per cent. The average annual

loss is extremely difficult to estimate, but, judging from the data gathered over a period of 20 years, it no doubt totals millions of dollars.

HOW TO RECOGNIZE WILT.

Cotton wilt may be suspected when plants wilt and die without any apparent reason. If the stem of a freshly wilted plant is cut across near the ground and found to be black or brown inside (fig. 1, *A*), this is strong evidence of the disease. Plants affected by wilt early in the season are considerably stunted as compared with healthy plants. Frequently the main stem of such a plant remains

FIG. 1.—Wilted cotton stalk cut across to show the blackening of the inside (*A*); cotton plant showing the main stalk stunted by wilt and one lower branch normally developed, only one side being infected (*B*).

short, while one or more of the lower branches grow normally. (Fig. 1, *B*.) The disease usually occurs first in irregular spots in the field (fig. 2), which increase in size from year to year. Wilt begins to kill plants early, and all through the season affected stalks die.

Wilt must be distinguished from another disease which occurs in parts of Texas and adjoining States and is known as Texas root-rot. (See description on pp. 27–28.)

HOW TO CONTROL WILT.

The planting of wilt-resistant varieties of cotton, combined with the use of proper crop rotations, is the only effective method now

known of controlling wilt. The fact can not be too strongly emphasized that the presence of root-knot (described on p. 10) in many sandy soils throughout the cotton belt makes the wilt more severe. It is therefore absolutely essential that lands infested with root-knot be planted in root-knot resistant crops for one or more years before wilt-resistant cotton is grown (see p. 11). The use of such a rotation will reduce the root-knot and make more certain a crop from a wilt-resistant variety of cotton.

USE WILT-RESISTANT VARIETIES OF COTTON. ROTATE TO REDUCE ROOT-KNOT.

FIG. 2.—Irregular area in cotton field, showing many plants killed and others stunted by wilt. Lamar, S. C.

RESISTANT VARIETIES ORIGINATED BY BREEDING.

Several wilt-resistant varieties of cotton have been bred by the United States Department of Agriculture, by State institutions, and by private individuals, and many thousands of acres of these varieties have been profitably grown on wilt-infested land for 15 or more years. The impression gained by some farmers that wilt-resistant varieties are much less productive than the varieties commonly grown is not warranted by the facts. Yields of a bale or more to the acre are frequently reported, and in addition the best yielding strains are very uniform and almost free from anthracnose.

Most of the commonly grown varieties of cotton are too susceptible to wilt to be profitable on badly diseased land. (Fig. 3.) In general, the large-bolled varieties are more susceptible to the disease than the small-bolled types. Experiments carried on by the Bureau of Plant Industry for the past 20 years have shown conclusively that wilt can be practically controlled in no other way than by the use of varieties specially bred for wilt resistance. (Fig. 4.)

The first wilt-resistant variety, Dillon, was bred by the Bureau of Plant Industry from the old Jackson Limbless. It was productive and highly resistant to wilt and was quite widely grown before other more desirable types were available. The fact that it was a cluster cotton, and therefore rather hard to pick, made it undesirable to many farmers. It has now been largely replaced by the Dixie,

FIG. 3.—Cotton variety test on wilt land, showing great differences in resistance. *A* and *C*, hybrid cottons, *A* being very subject to wilt, while *C* is highly resistant to wilt; *B*, Half and Half, nearly all killed by wilt while young. Americus, Ga.

which was the second resistant variety developed by the Bureau of Plant Industry. This variety is of the Peterkin type, with long, fruiting branches. (Fig. 5.) It has oblong, medium-sized bolls, is easy to pick, and is now more widely grown than any other wilt-resistant variety. The Dixie is productive, medium early, has a staple seven-eighths to 1 inch long, and small seeds with brownish-white fuzz. It yields 36 to 38 per cent of lint.

During the past few years other wilt-resistant varieties of cotton which are earlier than Dixie have been bred by the United States Department of Agriculture and are especially adapted for use in sections where the boll weevil is present. The most promising of

these is known by the name of Dixie-Triumph. Its principal advantages are larger bolls, larger yield, and earlier maturity than the Dixie. Another variety of considerable promise is the Dixie-Cook, which is very similar to the Dixie-Triumph and quite as productive on infested land.

Several promising wilt-resistant varieties have also been developed by Mr. A. C. Lewis, of the Georgia State Board of Entomology, and are being grown to a considerable extent in Georgia. Information regarding these varieties can be obtained by writing to Mr. Lewis at Atlanta, Ga. Resistant strains, some of which have considerable merit, have also been developed by a few individual farmers.

FIG. 4.—Wilt-resistant Dillon cotton growing on soil badly infested with wilt at Lamar, S. C.

HOW TO OBTAIN WILT-RESISTANT SEED.

Wilt-resistant varieties are produced only by careful selection and breeding over a period of years. It will not pay the average farmer to try to develop resistant strains for his own use, as much time and very careful attention are required to perfect them. The best way to secure wilt-resistant seed is to purchase it from a reliable breeder or grower and increase the strain by planting on wilt-infested land, using special care to save planting seed only from plants which do not wilt or show any signs of the disease. The growing of wilt-resistant cotton for seed for more than one year on land not infested with cotton wilt is to be discouraged, since this practice allows the nonresistant plants to increase without there being any way of distinguishing them, while if grown on wilt land they would either die from the disease or be discarded when selections were made.

It is furthermore necessary to practice careful selection and handling in order to maintain the wilt-resistant quality in the cotton, since otherwise it is gradually lost through natural crossing in the field, mixture of seed at the gins, and in other ways. Unless a farmer is prepared to give special attention to the selection of his seed every year in order to maintain its wilt resistance, it is advisable for him to procure from a breeder or grower a new supply of highly resistant seed every two or three years. This is especially true where seed is saved from fields free from or not thoroughly infested with wilt. The reputation of the Dixie has suffered in some cases by farmers selling and planting as Dixie seed secured several years previously from breeders which had not been properly selected to maintain its wilt resistance. The fact can not be too strongly emphasized that constant and careful selection must be practiced in order to maintain the wilt resistance of Dixie or any other variety of cotton.

FIG. 5.—Typical plant of Dixie wilt-resistant cotton.

The seed stocks of Dixie, Dixie-Triumph, and Dixie-Cook are being grown and improved by farmers in several Southern States under the supervision of the United States Department of Agriculture, and lists of growers of the best strains, from whom seed can be purchased at reasonable prices, can be secured through the county demonstration agents.

WILT CAUSED BY A FUNGUS.

The wilt disease of cotton is caused by a fungus (*Fusarium vasinfectum*) which enters the roots of the plants from the soil. It grows in the water-carrying vessels of the plants, plugging them and thus shutting off the water supply and causing the plants finally to wilt and die.

Wilt occurs most generally and severely on sandy land. Its occurrence on clay soil is unusual, though several such cases have been reported from South Carolina and Georgia. Wet seasons are more favorable to the disease than dry, and hence the losses are more severe then. Wilt may be spread from field to field by animals, tools, men,

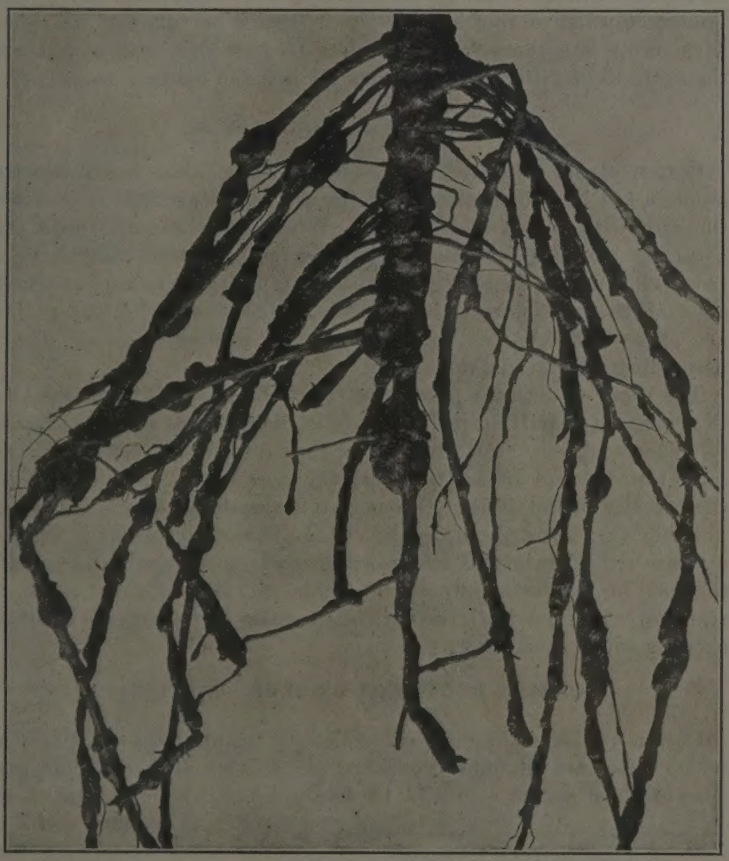

FIG. 6.—Root system of a cotton plant severely attacked by root-knot.

wind, drainage water, or any other agencies which carry the fungous spores. So far as is known, the disease is not carried in or on the seed. Experiments were carried on for four years in which seed was saved from badly wilted plants and planted the following season on sandy land where the disease had never been known, and yet no wilt occurred.

ROOT-KNOT.

Root-knot is next in importance to wilt from the standpoint of money loss to the cotton crop. This disease is more widespread in its occurrence than wilt, though it is found chiefly on the same types and areas of sandy soils. With the exception of the crops mentioned later in the list of root-knot resistant strains or varieties, all other farm crops are more or less subject to root-knot attack and are therefore to be avoided in rotations for infested fields.

APPEARANCE OF SICK PLANTS.

Cotton plants severely attacked by root-knot alone are distinctly stunted, but are not noticeably deformed above ground, as is often the case with plants having wilt. Where the disease is mild the dwarfing may not be noted. Both leaves and stems may have a pale yellowish green color, though this is not always very marked, since all the plants are usually affected alike, and no healthy plants are present for comparison. During dry weather diseased plants may wilt in the middle of the day.

The roots of diseased plants are covered with galls from the size of a pinhead to half an inch or more in diameter, as shown in figure 6. They may occur on the fine feeding rootlets as well as on the large taproot, and are scattered or very close together, depending on the severity of the disease. Young galls are almost white, but when old they turn brown and decay. They are very irregular in shape, and are enlargements of the roots themselves. These galls cut off the food and water supply of the plants and are the direct cause of stunting, while the death of parts of the roots gives entrance to other enemies which cause further damage.

CONTROL ROOT-KNOT BY CROP ROTATION.

Cotton root-knot can be controlled by using crop rotations in which root-knot immune crops are planted on diseased fields and susceptible crops are avoided. On badly diseased fields a rotation of two or three years is advised, and even then not more than one susceptible crop should be grown before planting again with resistant crops. On less-diseased fields a one-year rotation, including a root-knot resistant summer legume and two crops of winter grain may be sufficient.

ROTATE WITH GRAINS, CORN, AND ROOT-KNOT RESISTANT LEGUMES.
AVOID SUSCEPTIBLE CROPS.

In order that safe rotations may be intelligently planned it is necessary to know what crops and plants are immune or susceptible to root-knot. A list is therefore given below.

Crops largely or entirely immune to root-knot.

Barley.
Bean, soy (Laredo variety only).
Bean, velvet.
Beggarweed, Florida.
Chufas.
Corn.
Cowpea, Brabham.
Cowpea, Iron.
Cowpea, Monetta.
Cowpea, Victor.
Grass, Bermuda.
Grass, crab.
Grasses (nearly all).
Kafir.
Millets (nearly all).
Milo.
Oats, winter.
Peanut.
Rye.
Sorghum.
Wheat.

Crops not very severely attacked by root-knot.

Alfalfa.
Asparagus.
Bean, snap.
Cabbage.
Cane, sugar.
Clover, sweet.
Collard.
Cotton.
Pea, garden.
Potato, sweet.
Radish.
Spinach.
Strawberry.
Vetch, common.

Crops most severely attacked by root-knot.

Bean, Lima.
Bean, soy (all varieties except Laredo).
Beet.
Cantaloupe.
Carrot.
Celery.
Clover, bur.
Cowpea (all varieties except Iron, Brabham, Monetta, and Victor).
Cucumber.
Eggplant.
Fig.
Lettuce.
Okra.
Peach.
Potato.
Salsify.
Squash.
Tobacco.
Tomato.
Watermelon.

Weeds attacked by root-knot.

Balloon vine.
Clover, Mexican.
Fennel, sweet.
Maypop, or passion flower.
Papaya, or melon pawpaw.
Mayweed.
Purslane.

It is not possible to suggest a crop rotation which will fit the particular needs of every farmer. Each must work out the combination of resistant and susceptible crops which will be best adapted to his location and type of farming. Every root-knot rotation should include one or more of the legumes and some of the grain crops, all

of which are highly resistant to root-knot. For the northern Cotton States the root-knot resistant varieties of cowpeas are the most important legumes, though both early and late varieties of velvet beans can be advantageously planted. They are immune to root-knot attack. In the more southern Cotton States velvet beans stand first among root-knot resistant legumes, and their use has greatly increased during the past few years, since their merit has become better known. The root-knot resistant cowpeas and soy beans can also be used where desirable. The planting of susceptible crops on badly diseased fields will almost invariably result in large losses.

A typical two-year rotation which may be varied to suit local conditions is given herewith. Sow winter oats in the fall on the root-knot infested field. Plow them under in the spring and plant corn with Iron cowpeas between the rows; sow again to a winter grain crop and cut it for hay or grain in the spring; follow with Iron cowpeas and cut them for hay or seed; and plant a third winter grain crop and plow it under in time to plant wilt-resistant cotton the following spring. Any of the other immune crops listed above may be used in the rotation if desired.

HEAVY LOSSES DUE TO ROOT-KNOT.

Root-knot undoubtedly causes greater losses to farm crops than wilt, because of the fact that it attacks a large number of crops, while wilt affects cotton only (see p. 11). It occurs, like wilt, on the sandy Coastal Plain from Virginia to Texas, but it is probably more general and widespread. It also occurs in the Southwestern States, especially in southern California.

While it is most common and causes greater losses in sandy soils, it is known to occur also in some clay soils and especially in soils heavily fertilized with stable manure. The losses in some cases may run as high as 80 per cent. The average losses from root-knot for all sandy lands in a single county in South Carolina were estimated in 1917 at 4.4 per cent, based on a careful survey of over 20,000 acres in seven townships. For the State of Georgia in 1917 the cotton root-knot loss was estimated at 4.1 per cent of the crop. The average annual loss from root-knot for the entire cotton belt is estimated at approximately 200,000 bales of cotton and 100,000 tons of seed, worth about $16,480,000 at present prices. (December 2, 1920, with cotton at 14.38 cents per pound and seed at $21 per ton.)

It is essential that every cotton farmer realize that the damage caused by root-knot is not confined to the direct injury to the cotton plant by the nematodes. In addition, root-knot diseased plants are much more subject to wilt, and the two diseases occur very commonly together. For this reason cotton wilt is much worse following

root-knot susceptible cowpeas which have caused an increase of the eelworms in the soil. (Fig. 7.) Furthermore, the loss from root-knot is increased (1) by the greater cost of cultivation of infested land due to the growth of weeds where the cotton has died, (2) by the lowering of the market value of such land, and also (3) by the fact that badly diseased land must often be used for crops less profitable than cotton.

ROOT-KNOT CAUSED BY EELWORMS.

Root-knot of cotton and other crops is caused by tiny eelworms, or nematodes.[1] They bore into the roots from the soil and irritate them, causing the plant to form galls. If one of these galls is broken open, several pearly white rounded bodies about the size of a small pin-

FIG. 7.—Root-knot susceptible cowpeas make wilt worse. Cotton on left after Unknown cowpeas (susceptible); on right after Iron cowpeas (resistant).

head may often be seen with the naked eye. (Fig. 8, *A*.) These are the female eelworms full of eggs. The male worms are more elongated in shape, but too small to be readily seen without a lens. (Fig. 8, *B*.)

Root-knot is easily spread from one field to another by any means which will carry some of the infested soil or plant roots. Drainage water, cultivation, tools, and animals are all important agents in spreading the disease. Young nursery stock, young asparagus, cabbage, tomato, or other plants grown in diseased soil may carry the nematodes, as well as infested Irish or sweet potatoes used for seed purposes.

Further detailed information on root-knot and its control will be found in Farmers' Bulletin 648, entitled, "The Control of Root-

[1] *Heterodera radicicola.*

Knot," which will be sent free of charge upon application to the Secretary of Agriculture.

ANTHRACNOSE.

Cotton anthracnose is even more widespread than wilt, since it is known to occur in most of the cotton-growing sections of this country. It annually causes losses which range from slight to as high as 80 or 90 per cent of the crop, with an average estimated at from 1 to 3 per cent. The attacks of the disease vary with seasonal conditions and in general are worse in wet seasons.

DESCRIPTION OF THE DISEASE.

Anthracnose is commonly known to the farmer as boll-rot, or boll-spot, from the fact that the most conspicuous effect of the disease

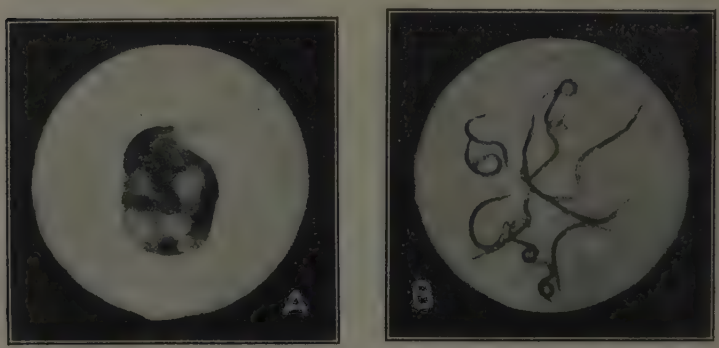

FIG. 8.—Adult female nematode full of eggs (*A*); young male and female nematodes (*B*). (Both illustrations greatly enlarged.)

is the rotting of the bolls, which occurs in the latter part of the season. The largest amount of damage is also caused by boll-rot.

On the bolls the disease first appears as small round water-soaked spots (fig. 9, *A*), which later may enlarge to include most or all of the boll, become black and finally have reddish borders and pink centers (fig. 9, *B*). The lint from such bolls is usually stained pink, or in the worst cases may be entirely rotten and worthless. Other rots often attack diseased bolls and complete the decay. Diseased bolls often fail to open because the locks have become stuck together.

Another boll-rot, which must be distinguished from anthracnose, is caused by the bacterial blight. In this the spots are at first water-soaked, later becoming black and shrunken, but they do not have the pink centers characteristic of anthracnose. The bacterial disease

also frequently attacks the stem of the boll and causes the entire boll to dry up, often before it is ripe. For a full description, see page 17.

Anthracnose also attacks the seedlings, killing the young sprouts even before they come through the ground. It often causes damping-off of the little plants or kills parts of the seed leaves during cool, wet weather, which is unfavorable for the growth of cotton (fig. 10). This damping-off is similar to that caused by the "sore-shin" fungus, Rhizoctonia (see p. 25), but the wilting is more sudden and the water-soaked appearance is more pronounced in the case of anthracnose attack.

The cotton stems are sometimes attacked by anthracnose, but this more commonly follows the bacterial black-arm (see p. 17).

Anthracnose lives over winter on diseased bolls or stems left in the field and on the seed from diseased plants.

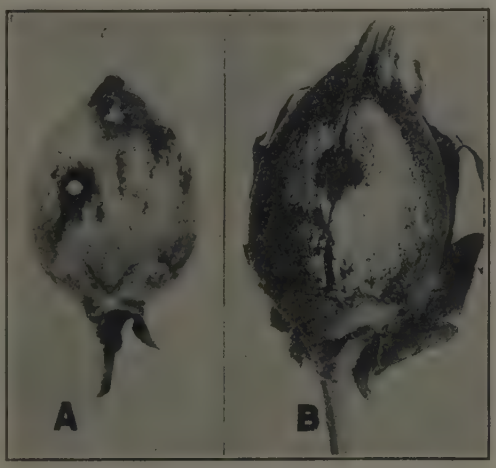

FIG. 9.—Cotton anthracnose on bolls: *A*, Early stage, small spot with water-soaked appearance and pinkish center; *B*, entire boll rotted by the fungus.

METHODS FOR CONTROLLING ANTHRACNOSE.

It has been found that the losses from anthracnose can be largely reduced by giving careful attention to seed selection and crop rotation. Seed for planting should be secured only from fields free from the disease or be selected from healthy plants at some distance from any which have diseased bolls. If seed of this kind can not be obtained, 3-year-old seed from slightly diseased fields may be used, since the disease dies out in the seed in that time. Other methods have been worked out for freeing seed from the disease which are useful for small lots of select seed, but are too

SELECT DISEASE-FREE SEED FOR PLANTING.
ROTATE CROPS.

expensive or otherwise not applicable to general use. Among these are seed treatment by sulphuric acid and mercuric chlorid (see p. 19).

Another method of reducing anthracnose losses is to plant varieties which are least troubled by this disease. The Toole, Dixie, Dixie-Triumph, King, Dillon, Cleveland, and Russell cottons are in general fairly free from anthracnose, while varieties like the Cook, Brown, Blue Ribbon, Half and Half, and Columbia are usually quite subject to injury. It will not pay to continue growing a variety which is known to be particularly susceptible to damage and loss by this disease.

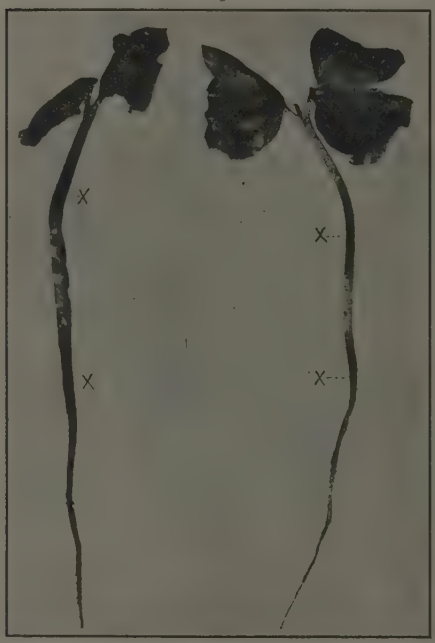

FIG. 10.—Cotton seedlings attacked by anthracnose. Note the blackened diseased areas at ×.

Since anthracnose may live over winter in the soil of diseased fields, it is important that crops be rotated, so that cotton will not be planted on land which grew a diseased crop the previous year. A 2-year rotation will give greater security against the overwintering of the disease in the soil.

ANTHRACNOSE CAUSED BY A FUNGUS.

Anthracnose is caused by a fungus[2] which grows into the bolls, stems, and leaves and kills their tissues, thus producing the rotten spots or dead areas. The fungus produces spores or tiny seeds in sticky masses on the diseased bolls and stems, giving the centers of the spots a pink color. By means of these the disease is spread from field to field and from plant to plant.

[2] *Glomerella gossypii.*

BACTERIAL BLIGHT.

APPEARANCE ON BOLLS, STEMS, AND LEAVES.

The only bacterial disease of cotton which is at present of economic importance is variously known as bacterial blight, bacterial boll-rot, angular leaf-spot, and black-arm, depending on the part of the plant attacked. The phase of the disease which results in much of the money loss to the crop is the attack on the bolls commonly known as boll-rot. The first signs of this trouble are small dark-green, water-soaked, roundish spots on the bolls (fig. 11, *A*), which gradually enlarge and turn black in the center as the tissues are killed and shrink (fig. 11, *B*). Frequently two or three locks or the entire boll are so injured that they fail to open, or if they do open the cotton produced is discolored and rotten (fig. 11, *C*). Often

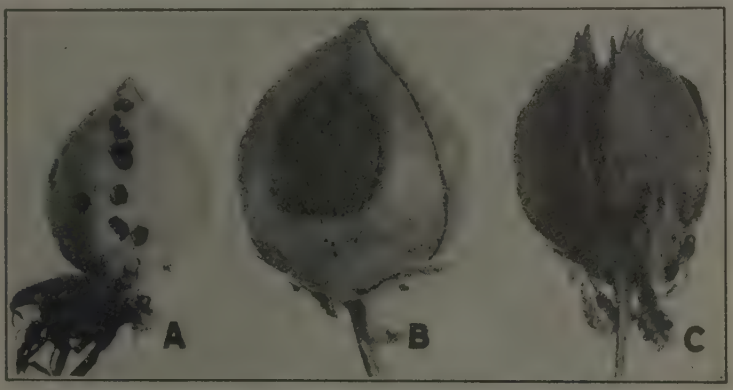

FIG. 11.—Bacterial boll-rot: *A*, Early; *B*, intermediate; and *C*, late stages.

the boll stem is attacked and killed, so that the boll dries up and falls off before maturity or fails to open.

The most general and conspicuous evidence of the disease occurs on the leaves, where it produces spots which are at first dark green, water soaked, and angular, bounded by the small veins. The spots are one-eighth to one-fourth of an inch in diameter and scattered over the leaves, often forming elongated diseased areas near the larger veins. Later they become dry, dark reddish brown to black, and sunken in the center and have a rusty red border. As the disease progresses the spots run together and increase in size. When severely attacked the leaves frequently turn yellow, curl up, and fall off. This phase of the trouble is usually called angular leaf-spot (fig. 12).

Black-arm is the name commonly applied to the disease when it attacks the stems of cotton plants, because the skin of the branches

is killed and they turn black. Frequently this phase of the disease is complicated by the secondary occurrence of the anthracnose fungus, which produces an abundance of pink spores on the blackened branches. Black-arm so weakens the stems that they may drop their bolls while still immature, or the stalks and fruiting branches may be broken off by storms (fig. 13). In severe cases entire plants are killed and the yield very seriously reduced. This is particularly

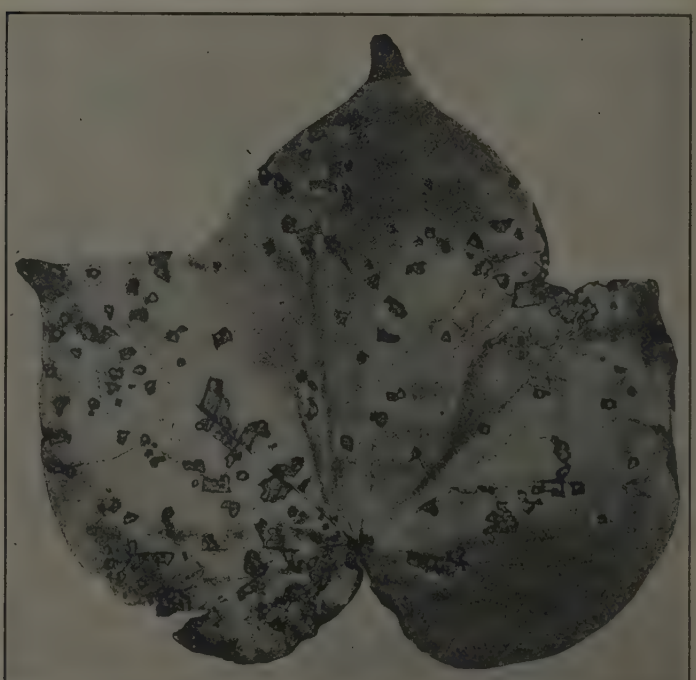

FIG. 12.—Angular leaf-spot of cotton. Many spots are bounded by the small veins.

true with Egyptian and Sea Island cottons, which are especially susceptible to the disease. This is also one of the principal reasons why Egyptian cotton has not been profitably grown in the Southeastern States.

On the young seed leaves the spots resemble those on the bolls, being round, water soaked, and green at first, but later becoming black.

HOW TO CONTROL BLIGHT.

The best method now known of controlling the bacterial blight of cotton involves the use of disease-free seed combined with

crop rotation. While crop rotation may not be as important a factor in controlling bacterial blight as originally thought, since it has been found that the disease apparently does not live over in the soil of diseased fields to a serious extent, nevertheless rotation is important as a general farming procedure and is valuable in the control of other diseases, such as anthracnose, and therefore should be regularly practiced.

ROTATE CROPS. SELECT DISEASE-FREE SEEDS.

It is known that the disease may live over winter on the seed to a certain extent, and it is therefore important that careful seed selection

FIG. 13.—Serious loss from "black-arm" results from the breaking of diseased branches during storms: *A*, An injured plant; *B*, a broken diseased branch (enlarged).

should be a regular part of good cotton-farming practice in order that only healthy seed be saved for planting. Seed should be saved only from fields where the disease does not occur, or if this is impossible, owing to its general prevalence, it should be taken from the least-affected fields or portions of fields or be secured from some other farm or locality where the disease has not been so severe.

METHOD OF SEED TREATMENT.

Under special conditions where it is desired to plant small quantities of valuable seed which came from badly diseased fields, treatment with sulphuric acid, mercuric chlorid, or hot water may be used to advantage to free the seed from disease germs, but seed treatment is not advised as a general farm practice.

The treatment of cotton seed is complicated by the presence of the fuzz, which, because of the air it holds, prevents the ordinary dis-

infectants, such as mercuric chlorid and formaldehyde, from coming in contact with the surface of the seed and thus thoroughly sterilizing it. For this reason it is necessary to use concentrated sulphuric acid to remove the fuzz. Because of the extremely caustic nature of this acid it should be used only by those who have had experience in handling it. For this treatment wooden tubs coated on the inside with melted roofing pitch have been found satisfactory, as the pitch is very resistant to the action of the acid. Three tubs should be provided, one of which has the bottom very closely perforated with quarter-inch holes, to furnish a sieve for draining off the acid and to assist in washing the seed after treatment.

Place the seeds to be treated in one of the tubs and pour enough concentrated acid over them to wet them completely. Stir the seeds thoroughly into the acid and continue the treatment 8 to 10 minutes until the lint has been removed. Then pour the seeds and acid into the perforated tub, supported over the second coated tub, and allow the acid to drain out. Then support the tub over a hole in the ground and quickly and thoroughly wash the acid from the seeds by pouring over them a large quantity of running water and stirring them constantly. This is the most critical part of the operation, for the temperature of the mass of seeds will become high enough to injure germination if sufficient water is not added to keep them cool. After the seeds are thoroughly washed spread them out on a roof or other convenient place to dry. The acid may be used until it becomes too thick to pass through the sieve; then wash it out of the seeds with the rinsing water.

DISTRIBUTION AND LOSS.

Bacterial blight occurs very generally throughout the cotton belt from Virginia to Texas and also in the southwestern cotton areas especially in Arizona. It appears to be more general and severe on the Coastal Plain than in the Piedmont region. Its occurrence in sufficient amount and seriousness to cause important crop injury depends on favorable weather conditions and varietal susceptibility. Dry weather checks the disease, while rainy weather is especially favorable to its rapid spread. In fact, wind during rainstorms is one of the most important agents in the dissemination of the blight.

There may be no loss from blight or the losses may aggregate 75 per cent or more in especially severe cases. Upland cotton in general is relatively resistant to damage as compared with Sea Island and Egyptian, most varieties of which are especially susceptible. Losses result from leaf shedding, from boll rotting, and from the killing or breaking of branches which have been attacked. The leaf-spot and dropping are probably the least serious phases of the disease, and the

boll-rot is the most injurious in Upland cotton. In Sea Island and Egyptian varieties black-arm is important and adds to the damage caused by boll-rot.

In the Eastern States a reduction of the yield by 5 per cent or more would be considered the exception, while an average injury of about 1 per cent is estimated on Upland cotton. On Egyptian cotton in the Salt River Valley, Ariz., the losses from the black-arm and boll-rot in 1918 and 1919 varied from 0 to 65 per cent, with an estimated average of 15 per cent.

BLIGHT CAUSED BY A GERM.

Blight is caused by a bacterium, or germ,[3] which enters the leaves, stems, and bolls through the breathing pores and kills the cells near by, producing spots on the leaves, dead areas on the branches, and the decay of the bolls.

The disease appears first on the cotyledons, or young stems, early in the season. Later on, if favorable weather conditions occur, it spreads to the leaves, bolls, and branches, causing the various phases of the trouble already described. One of the most effective agents in spreading the disease germs is wind-blown rain.

The causal organism of the disease lives over winter in or on the seed, and possibly on diseased parts of the cotton plant left in the field or plowed under in the fall.

SHEDDING OF BOLLS.

NATURE AND OCCURRENCE OF SHEDDING.

Shedding is the name commonly given to the premature dropping of cotton squares or young bolls at any time during the season. It does not include the dropping of bolls due to damage by weevils or other insects. It is not a disease in the usual sense of the word, but the large annual losses caused by it make it seem desirable to include a brief discussion of the trouble. Shedding occurs every season to a greater or less degree in every cotton field, and in the aggregate the loss from shedding is greater than that from all the cotton diseases combined. The cotton plant produces a larger crop of flowers than it can mature even under the most favorable growing conditions, and the percentage of those which are subsequently shed depends on the character of the succeeding season. There is also some variation among the different varieties as to the number of bolls shed. The results of careful records of the number of bolls shed by a thousand plants made by Ewing in Mississippi during a season when soil and weather conditions were very favorable indicates that losses of

[3] *Bacterium malvacearum.*

40 to 60 per cent of the bolls by shedding is a fairly common occurrence. Under exceptionally favorable weather conditions the losses may be less and under adverse conditions greater.

Shedding generally begins a week or more after the first flowers have bloomed and occurs usually in increasing degree up to the middle of August, when it decreases to the end of the season. Careful records indicate that in this country comparatively few flower buds or flowers are shed except under unusual conditions, but that by far the larger number of shed bolls are dropped within a period of two weeks after the opening of the flowers. This period of persistence of the shed bolls varies with different varieties and at different stages in the fruiting season. It is usually longest early in the summer, sometimes as much as 19 days, and shortest toward the close of the season, when four to five days is the average.

In most varieties the dead bolls fall to the ground, but in the cluster varieties it is more usual for them to remain attached to the plant. This fact accounts for the general impression that cluster varieties are more subject than other cottons to shedding injury.

The first indication of shedding is a gradual fading of the normal green color of all parts of the boll. In varieties which retain the bolls they soon become pale yellow or straw color, dry up, and may remain attached to the plant until the end of the season.

CAUSE OF SHEDDING.

The shedding of cotton bolls may be due to one or more of many causes, among which may be noted the following: High temperatures, resulting in high transpiration and evaporation and consequent low soil moisture; heavy and continuous rains; abrupt changes in weather conditions from wet to dry, cloudy to clear, cool to hot, or the opposite; imperfect pollination due to rainy weather; and root injury due to too deep cultivation late in the season.

Experimental workers agree that shedding is most closely related to the water supply of the plant. Barre has shown that the water requirements of cotton in South Carolina are largest during the month of August, and this is also the time when the temperatures are highest and the soil-moisture content lowest. Lack of sufficient soil moisture is the principal factor causing cotton shedding.

Shedding may be regarded as a means by which the plant adjusts itself to changed growing conditions. During the early part of many seasons the temperature and moisture conditions are usually more favorable to vegetative growth than later, and hence the cotton plant produces a larger weed and sets more flowers than it can maintain during the latter part of the season when temperatures are higher, soil moisture less, and, in many instances, readily available plant food

is used up, and when the fruiting activities of the plant are more exacting on the food and water supply. Consequently, when these conditions of increased demand and decreasing supply of food and water arrive, the plant meets them by shedding bolls until a point is reached where the remainder can be matured under the less favorable growth conditions. This process of adjustment to meet changed conditions is continuous, and hence the amount of shedding varies from time to time. In cases of extreme drought bolls of considerable size may be shed.

On the other hand, water-logging of the soil due to lack of drainage and excessive and continuous rainfall may also result in a considerable amount of shedding.

CONTROL OF SHEDDING.

Since the lack of soil moisture during the latter part of the season is the principal cause of shedding, methods of conserving the water supply will help to reduce the losses. The most important methods are (1) building up the vegetable-matter content of the soil by crop rotations, by plowing under green-manure crops, or by the addition of liberal quantities of stable manure; and (2) shallow cultivation in order to retain a loose soil mulch to prevent evaporation, as long as it can be done without injury to the plants.

ADD HUMUS TO THE SOIL.
CULTIVATE SHALLOW
LATE IN THE SEASON.

Avoid injuring the cotton roots by deep cultivation late in the season. Drain wet fields to reduce water-logging in rainy seasons.

RUST.

OCCURRENCE AND LOSSES.

One of the most common and serious troubles affecting cotton on the poorer soils throughout the cotton belt is generally known as rust. Other names are black rust, yellow leaf-blight, and potash hunger. It occurs quite generally on the worn-out and light sandy soils, and in the aggregate the losses are large. In 1918 the trouble was reported as causing the most serious losses in the Coastal Plain regions of South Carolina, North Carolina, Georgia, and Alabama, and also locally in Mississippi and Louisiana and on the "buckshot" lands of Arkansas.

The losses range from slight to as much as 50 or 60 per cent, with an estimated average for the entire cotton belt of 4 to 5 per cent.

HOW TO RECOGNIZE RUST.

Cotton fields affected by the common rust do not usually produce normal growth. The plants are small and lack a healthy green color. The leaves first begin to show a yellowish mottled appearance about the middle of the season, the parts near the veins remaining green longest, while the tissues between the veins, and hence farthest from the food supply, turn yellow. They later take on a reddish brown color, curl up, and drop off, leaving the stalk bare. The top bolls of such plants either fail to set or mature imperfectly, so that the lint produced is short and of inferior quality.

The trouble is usually noted in definite spots or irregular areas in affected fields (fig. 14), and unless remedial measures are applied may recur year after year in the same places.

FIG. 14.—Cotton rust appears in irregular spots in the fields, where but little cotton is produced.

This disease is liable to be confused with certain other cotton troubles, especially with the true rust caused by a fungus attacking the leaves (described on p. 31) and with injury caused by red-spider attacks. Red-spider injury is also referred to as red-rust. These mites attack and cause a reddening of a part or all of the leaf. In extreme cases defoliation of affected plants results. The mature red spiders or the yellowish younger ones, together with their fine webs, can usually be found on the under side of the discolored leaves, and thus the trouble can be distinguished from rust.

CONTROL OF RUST.

Cotton fields which show general and severe rusting are usually in need of rotation with other crops in order to build up the humus supply which has been exhausted by continuous cotton cropping. The plowing under of green-manure crops, such as rye, cowpeas,

and velvet beans, or the addition of a liberal application of stable manure will do much to improve soil conditions and prevent rust.

SUPPLY VEGETABLE MATTER TO THE SOIL. USE FERTILIZERS CONTAINING POTASH. DRAIN THE WET FIELDS.

The use of kainit at the rate of 200 pounds per acre, or of 50 pounds per acre of muriate of potash, or the application of other potash-containing fertilizers will also help reduce rust damage.

CAUSE OF RUST.

Rust is a reaction of the cotton plant to soil conditions unfavorable to normal growth and development. It is not due to the attack of any disease-producing organism or to injury by insects.

The most common causes for rust are lack of humus or vegetable matter in the soil, lack of potash, and lack of drainage. Many fields with naturally light or poor soils are planted to cotton year after year with little or no attention to keeping up the supply of vegetable matter which is essential to vigorous growth. The result is an increasing occurrence of rust the longer the practice is maintained. Such soils are also usually deficient in potash, and if it is not supplied in sufficient amounts in the fertilizers rust will develop when the supply furnished is used up by the plant. Rust, or potash hunger, has been more general and serious the past few years, owing to the difficulty of securing the normal supply of potash on account of the war.

Rust often develops in poorly drained fields or in low spots, while higher parts are free from it. Likewise, some fields may develop rust as a result of heavy and continuous rains in the latter part of the season.

SORE-SHIN.

The disease commonly called sore-shin attacks chiefly the small cotton seedlings, causing them to rot off partly or entirely at or near the surface of the ground. It sometimes causes considerable damage during cool wet periods early in the season by reducing the stand of plants so much that replanting is necessary or by so injuring the seedlings that growth is retarded and the normal development of the crop delayed. It rarely causes important damage in favorable seasons, owing to the general practice of very heavy seeding.

HOW TO RECOGNIZE SORE-SHIN.

The trouble is characterized by the presence of dark rusty brown sunken cankers on the seedling stems at or just below the surface of the soil. In severe cases these encircle the stem or penetrate so

deeply that the plants fall over and die. Many plants which have stem cankers but are not too severely affected recover on the arrival of warm dry weather and outgrow the injury, though somewhat delayed in development. Sore-shin must be distinguished from the damping-off due to anthracnose. In sore-shin more definite ulcers are formed; they are rusty brown in color and are generally found just at or below the soil surface. In anthracnose the injury is a more rapid damping-off, often occurring as long sunken reddish areas on the stem above ground, and it is usually associated with diseased spots on the seed leaves.

FIG. 15.—Cotton plant wilted by root-rot; two healthy plants stand beside it.

CONTROL OF SORE-SHIN.

No very satisfactory control methods are known. The best practice is to fertilize the plants adequately to start them off into vigorous growth and to cross harrow the rows with a weeder to allow the soil near the seedling stems to dry out as quickly as possible after wet periods.

SORE-SHIN CAUSED BY A SOIL FUNGUS.

Sore-shin is due to a fungus (Rhizoctonia) which lives in the soil and attacks the seedlings during cool moist weather. Because of the nature of the injury many farmers attribute the trouble to cuts or blows from a hoe or scraper.

TEXAS ROOT-ROT.

SIGNS OF THE DISEASE.

The first indication of Texas root-rot is the sudden wilting of one or more cotton plants (fig. 15). This is usually noted the latter part of June or early in July, though cases have been noticed early in May. Following these first cases other plants near by or in other parts of the field continue to wilt and die throughout the season. By October rounded patches or irregular areas of considerable extent may be found where the cotton stalks are dead and reddish brown (fig. 16). The suddenness of the wilting and death of affected plants is very noticeable, as are the brown areas of dead plants in comparison with the remaining parts of the field, which are still green and healthy. The rate of wilting is somewhat dependent on weather conditions, the disease progressing more rapidly during

FIG. 16.—A root-rot spot in a cotton field, showing dead, wilted, and healthy plants.

warm days immediately following rainy weather than during dry periods. The wilted plants become entirely dry in 12 to 24 hours of sunshiny weather.

Aboveground symptoms prior to wilting are not readily noted. No appreciable dwarfing of the plant or yellowing of the foliage is present, such as characterize plants attacked by wilt or black-root (p. 3).

The roots are usually covered at first with a whitish mold, which later becomes yellowish brown. This results from the growth of the fungus which causes the disease. The taproot is usually attacked first near the surface of the ground. Affected roots are generally slightly shrunken, and the sunken, diseased areas are at first bordered by a reddish discoloration, which later becomes brown. Often there is a slight enlargement of the stem of the plant above the diseased part of the taproot and near the soil surface, from which

new secondary roots are put out to take the place of the diseased ones. It is quite common to find the taproot entirely dead from root-rot and a single lateral root abnormally developed to support the plant (fig. 17).

Apparently healthy plants adjacent to wilted ones may have their roots covered with the fungous growth, which may later kill them. The affected areas in fields usually enlarge from year to year by the growth of the fungus through the soil, by means of diseased soil carried on tools, or by other agencies. There are some indications that the disease dies out to a certain extent in the center of diseased spots while advancing at the outer edge, in a manner similar to that characteristic of the well-known "fairy rings."

CONTROL MEASURES.

PLOW DEEPLY IN THE FALL. ROTATE CROPS.

Texas root-rot is difficult to control, and no entirely satisfactory methods are known. The best-known measures for reducing losses from the disease combine crop rotation and deep fall plowing.

Since the disease attacks numerous crops besides cotton and also certain weeds, the following list is given of plants susceptible and resistant to Texas root-rot. Susceptible crops should not be grown on land affected with the disease. Crops resistant to root-rot should be made the basis of rotations for controlling the disease.

Plants attacked by Texas root-rot.	*Crops immune to Texas root-rot.*
Cotton.	Corn.
Soy beans.	Sorghums.
Cowpeas.	Millet.
Sweet potatoes.	Wheat.
Alfalfa.	Oats.
Most nursery stock and fruit trees.	Other grains.
Many shade trees.	
Beets and other vegetables.	

Combined with crop rotation, deep fall plowing to effect a thorough aeration of the soil should be occasionally practiced when the diseased land can be worked without injury to its physical condition. The land should be plowed late in November or early in December to a depth of 7 to 9 inches and left exposed to the weather during the winter. A 3-year rotation, using corn, grains, and sorghums, has been found most effective in reducing root-rot damage, though shorter rotations will give a certain measure of relief.

DISTRIBUTION, DAMAGE, AND SPREAD.

The occurrence of Texas root-rot on cotton is confined to the Southwestern States, Texas, Oklahoma, Arkansas, Arizona, New

Mexico, and southern California. In Texas it is most serious on the black-waxy limestone soils, which ordinarily are poorly drained and aerated, though it also occurs on other soils. Its spread northward and eastward is apparently limited by soil types and by low winter temperatures, which appear to kill the causal fungus. Root-rot may spread in the field quite rapidly during favorable seasons, probably by direct growth of the causal fungus through the soil, by soil adhering to tools or animals, and on bits of soil scattered by the wind. It is probably carried from diseased fields to healthy ones by the transfer of soil, such as takes place when soil inoculated with the nitrogen-gathering organisms is taken from an old alfalfa field to a new location where an alfalfa crop is to be started. This practice should be discouraged, since the root-rot is injurious not only to cotton but to alfalfa and will undoubtedly lead to more rapid spread of the trouble.

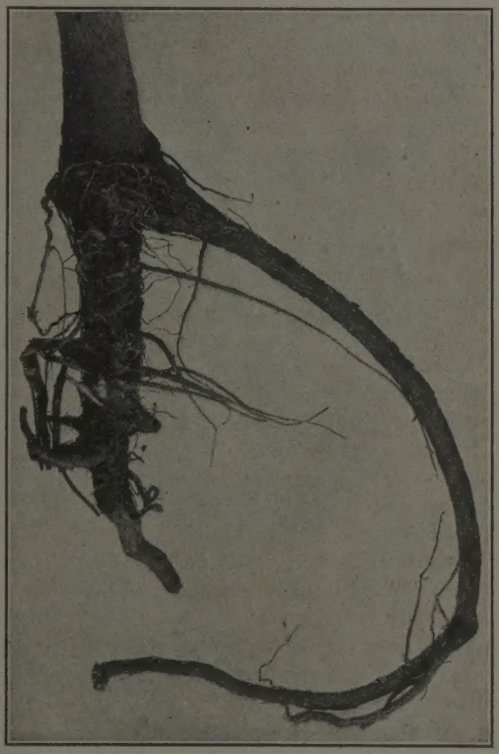

FIG. 17.—Root system of a cotton plant attacked by root-rot, showing its taproot killed and a lateral root developed to support the plant.

The damage from root-rot varies from slight to very severe. Sometimes the disease attacks the plants so late in the season that a fair crop is matured before they die, but in most cases the yield of diseased plants is materially reduced and the quality of the lint is inferior, while plants killed early in the season produce no cotton. In Texas, root-rot is the most destructive disease of cotton, some planters regarding it a more serious menace to the crop than the cotton boll weevil. The fact that it attacks several other crops besides cotton adds to the damage which it may cause. In 1906 the

loss from root-rot in Texas alone was estimated at 52,600 bales, or 1.3 per cent of the crop. The disease is found to an increasing extent in the newly-developed cotton areas in New Mexico and Arizona.

ROOT-ROT CAUSED BY A SOIL FUNGUS.

Root-rot is attributed to a fungus[4] which lives in the soil and attacks and kills the roots of cotton and other plants. It penetrates the roots and causes the wood to turn black. It grows in the water vessels as well as the other parts of the roots, but does not spread to the stems and branches, as does the fungus which causes wilt (p. 4), so common in the sandy soils of the southeastern Cotton States. The fungus seems to grow best, and hence the disease is most severe, where the soil aeration is the poorest.

MINOR DISEASES.

In addition to the more important cotton diseases already described there are several other troubles which each year cause a certain amount of damage that is difficult to estimate. They are not considered of major importance, but are worthy of brief mention.

Leaf-spot of cotton is caused by a fungus[5] which produces an abundance of rather small roundish to irregular spots which are white in the center, with a reddish brown border. This leaf-spot is seen in nearly every cotton field toward the end of the season. It is doubtful whether it causes appreciable damage, except when so severe as to cause defoliation.

Leaf-blight is due to the attacks of a fungus[6] which produces rusty brown dead spots one-fourth to three-fourths of an inch in diameter, of irregular shape, and showing concentric ridges. These spots are more commonly associated with the angular leaf-spot injuries or are found in areas attacked by red spiders, but they may also occur independently. It is less common than the Cercospora leaf-spot.

Areolate mildew, or frosty blight, produces small scattered angular spots which are usually frosty white on the under side of the leaves (fig. 18), due to the fruiting bodies of the causal fungus,[7] while from the upper side the diseased areas are sometimes reddish and sometimes white. This disease occurs occasionally toward the end of the season, especially on the leaves of plants growing in moist places, and in the more severe cases causes partial defoliation. It is of less general occurrence and of less importance than Cercospora leaf-spot.

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[4] *Ozonium omnivorum.*
[5] *Cercospora gossypina.*
[6] *Alternaria* sp.
[7] *Ramularia areola.*

True rust is a fungous[8] disease of very general occurrence in the West Indies, but which has been reported only once from this country. It is characterized by the presence on the leaves of numerous

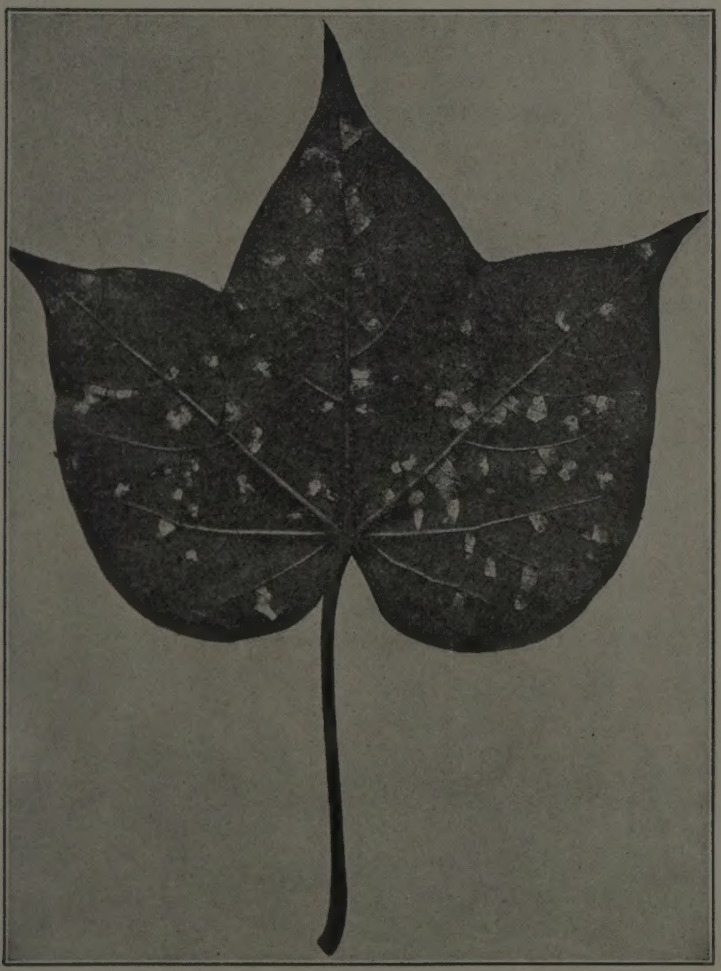

FIG. 18.—Under side of a cotton leaf attacked by areolate mildew, or frosty blight.

slightly raised, rusty-brown circular spots about the size of a pinhead. It is distinctly different from the disease commonly called rust, which is described on page 24.

[8] *Uredo gossypii.*

Diplodia boll-rot is reported as causing as high as 10 per cent loss in occasional fields in Louisiana, with an estimated average of 2 per cent loss for the State, though it is not so abundant in the eastern Cotton States. It is caused by a fungus[9] which enters the boll through insect injuries or wounds made by other diseases, but it is not able to attack uninjured bolls. Affected bolls first become brown, then jet black, and are covered with a powdery coating of spores. When bolls become infected, the rot develops rapidly, involving the entire boll; the lint is decayed and blackened and of no value. It occurs most often on the lower bolls near or in contact with the soil. Crop rotation is advised where the rot becomes important, since the causal fungus is known to live over winter in the soil on decaying bolls and stalks.

Fusarium boll-rot also occurs on bolls injured by insects or other diseases and is especially prevalent in wet weather. It is usually recognized by an abundant covering of pink spores. It is distinguished from anthracnose boll-rot by the fact that anthracnose spores are borne in sticky masses, usually on the central part of the spot, while Fusarium spores are lighter pink and are produced in powdery masses over the entire surface of the decayed area. The disease is not of great importance except in wet seasons, when it causes the rotting of a good many injured bolls. The fungus lives over winter in the field and on the seed and also attacks the young seedlings.

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[9] *Diplodia gossypina.*

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